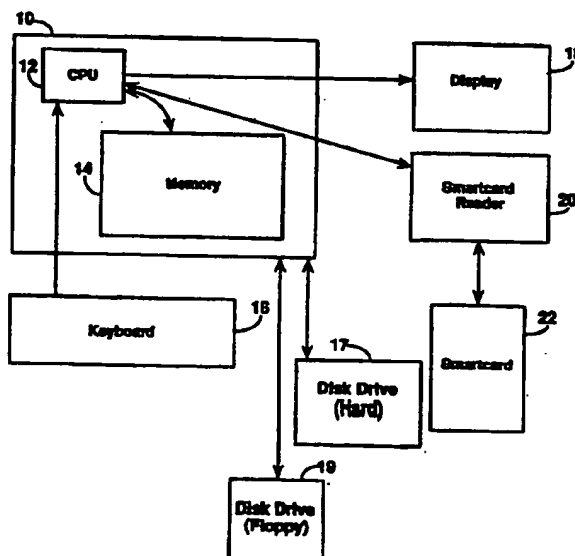




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(54) Title: **SYSTEM FOR PROTECTING COMPUTERS VIA INTELLIGENT TOKENS OR SMART CARDS**

(57) Abstract

The possibility of corruption of critical information required in the operation of a host computer (10) is reduced by storing the critical information in a device (22); communicating authorization information between the device (22) and the host computer (10); and causing the device (22), in response to the authorization information, to enable the host computer (10) to read the critical information stored in the device (22). The device (22) includes a housing, a memory (36) within the housing containing information needed for startup of the host computer (10), and communication channel for allowing the memory (36) to be accessed externally of the housing. The device (22) is initialized by storing the critical information in memory (36) on the device (22), storing authorization information in memory (36) on the device (22), and configuring a microprocessor (34) in the device (22) to release the critical information to the host computer (10) only after completing an authorization routine based on the authorization information.

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SYSTEM FOR PROTECTING COMPUTERS VIA
INTELLIGENT TOKENS OR SMART CARDS

Background of the Invention

5 This invention relates to reducing the possibility of corruption of critical information required in the operation of a computer system. In particular, the invention is aimed at preventing boot-sector computer viruses and protecting critical executable code from
10 virus infection.

 The process of starting up a computer, i.e., booting or boot-strapping a computer is well known, but we describe aspects of it here for the sake of clarity and in order to define certain terms and outline certain
15 problems which are solved by this invention.

 Fig. 1 depicts a typical computer system 10 with central processing unit (CPU) 12 connected to memory 14. Display 18, keyboard 16, hard disk drive 17, and floppy disk drive 19 are connected to computer system 10.

20 A typical computer system such as shown in Fig. 1 uses a program or set of programs called an operating system (OS) as an interface between the underlying hardware of the system and its users. A typical OS, e.g., MS-DOS Version 5.0, is usually divided into at
25 least two parts or levels. The first level of the OS, often referred to as the kernel of the OS, provides a number of low-level functions called OS primitives which interact directly with the hardware. These low-level primitives include, for example, functions that provide
30 the basic interface programs to the computer system's keyboard 16, disk drives 17, 19, display 18, and other attached hardware devices. The OS primitives also include programs that control the execution of other programs, e.g., programs that load and initiate the
35 execution of other programs. Thus, for example, if a

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user wishes to run a word-processing program or a game program, it is the primitives in the OS kernel which load the user's program from a disk in one of the attached disk drives 17, 19 into the computer system's memory 14 and begins executing it on CPU 12.

The second level of the OS typically consists of a number of executable programs that perform higher-level (at least from a user's perspective) system related tasks, e.g., creating, modifying, and deleting computer files, reading and writing computer disks or tapes, displaying data on a screen, printing data, etc. These second-level OS programs make use of the kernel's primitives to perform their tasks. A user is usually unaware of the difference between the kernel functions and those which are performed by other programs.

A third level of the OS, if it exists, might relate to the presentation of the OS interface to the user. Each level makes use of the functionality provided by the previous levels, and, in a well designed system, each level uses only the functionality provided by the immediate previous level, e.g., in a four level OS, level 3 only uses level 2 functions, level 2 only uses level 1 functions, level 1 only uses level 0 functions, and level 0 is the only level that uses direct hardware instructions.

Fig. 2 depicts an idealized view of a four level OS, with a level for hardware (level 0) 2, the kernel (level 1) 4, the file system (level 2) 6, and the user interface (level 3) 8.

An OS provides computer users with access and interface to a computer system. Operating systems are constantly evolving and developing to add improved features and interfaces. Furthermore, since an OS is merely a collection of programs (as described above), the same computer system, e.g. that shown in Fig. 1, can have

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a different OS running on it at different times. For example, the same IBM personal computer can run a command-line based OS, e.g., MS-DOS V5.0, or a graphical, icon based OS, e.g., MS-Windows 3.0.

5 In order to deal with the evolution of operating systems (as well as to deal possible errors in existing operating systems) computer system manufacturers have developed a multi-stage startup process, or boot process, for computers. Rather than build a version of the OS
10 into the system, the multi-stage boot process works as follows:

A boot program is built into the computer system and resides permanently in read-only memory (ROM) or programmable read-only memory (PROM) (which is part of
15 memory 14) on the system. Referring to Fig. 4, a computer system's memory 14 can consist of a combination of Random Access Memory (RAM) 24 and ROM 26. The ROM (or PROM) containing the boot program is called the boot ROM 28 (or boot PROM). A boot program is a series of very
20 basic instructions to the computer's hardware that are initiated whenever the computer system is powered up (or, on some systems, whenever a certain sequence of keys or buttons are pressed). The specific function of the boot program is to locate the OS, load it into the computer's
25 memory, and begin its execution. These boot programs include the most primitive instructions for the machine to access any devices attached to it, e.g., the keyboard, the display, disk drives, a CD-ROM drive, a mouse, etc.

To simplify boot programs and to make their task
30 of locating the OS easy, most computer system manufacturers adopt conventions as to where the boot program is to find the OS. Two of these conventions are: the OS is located in a specific location on a disk, or the OS is located in a specific named file on a disk.
35 The latter approach is adopted by the Apple Macintosh™

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computer where the boot program looks for a file named "System" (which contains, e.g., Apple's icon-based graphical OS) on disks attached to the computer. The former approach, i.e., looking for the OS in a particular location, e.g., on a disk, is the one currently used by most I.B.M. personal computers (and clones of those systems). In these systems the boot program looks, in a predetermined order, for disks in the various disk drives connected to the system (many computer systems today have a number of disk drives, e.g., a floppy-disk drive, a CD-ROM, and a hard-disk drive). Once the boot program finds a disk in a disk drive, it looks at a particular location on that disk for the OS. That location is called the boot sector of the disk.

Referring to Fig. 3, a physical disk 9 is divided into tracks which are divided up into sectors 11 (these may actually be physically marked, e.g., by holes in the disk, in which case they are called hard-sectored, but more typically the layout of a disk is a logical, i.e. abstract layout). The boot sector is always in a specific sector on a disk, so the boot program knows where to look for it. Some systems will not allow anything except an OS to be written to the boot sector, others assume that the contents of the boot sector could be anything and therefore adopt conventions, e.g., a signature in the first part of the boot sector, that enables the boot program to determine whether or not it has found a boot sector with an OS. If not it can either give up and warn the user or it can try the next disk drive in its predetermined search sequence.

Once the boot program has determined that it has found a boot sector with an OS (or part of an OS), it loads (reads) into memory 14 the contents of the boot sector and then begins the execution of the OS it has just loaded. When the OS begins execution it may try to

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locate more files, e.g., the second level files described above, before it allows the user access to the system. For example, in a DOS-based system, the program in the boot sector, when executed, will locate, load into
5 memory, and execute the files, IO.SYS, MSDOS.SYS, COMMAND.COM, CONFIG.SYS, and AUTOEXEC.BAT. (Similarly, in a multi-level system, each level loads the next one, e.g., the Hewlett-Packard Unix™-like System HPUX has at least 4 levels which get loaded before the user is
10 presented with an interface to the computer system.)

The process of booting a computer system is sometimes called the boot sequence. Sometimes the boot sequence is used to refer only to the process executed by the first boot program.

15 Computer viruses aimed at personal computers (PCs) have proliferated in recent years. One class of PC viruses is known as boot infectors. These viruses infect the boot-sectors of floppy or hard disks in such a way that when the boot sequence of instructions is initiated,
20 the virus code is loaded into the computer's memory. Because execution of the boot sequence precedes execution of all application programs on the computer, antiviral software is generally unable to prevent execution of a boot-sector virus.

25 Recall, from the discussion above, that the boot program loads into memory the code it finds in the boot sector as long as that code appears to the boot program to be valid.

In addition to the boot infector class of viruses,
30 there is another class of viruses called file infectors which infect executable and related (e.g., overlay) files. Each class of virus requires a different level or mode of protection.

File infector viruses typically infect executable
35 code (programs) by placing a copy of themselves within

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the program; when the infected program is executed so is the viral code. In general, this type of virus code spreads by searching the computer's file system for other executables to infect, thereby spreading throughout the
5 computer system.

One way that boot-sector viruses are spread is by copying themselves onto the boot-sectors of all disks used with the infected computers. When those infected disks are subsequently used with other computers, as is
10 often the case with floppy disks, they transfer the infection to the boot-sectors of the disks attached to other machines. Some boot-sector viruses are also file infectors. These viruses copy themselves to any executable file they can find. In that way, when the
15 infected file is executed it will infect the boot sectors of all the disks on the computer system on which it is running.

Recall, from the discussion above, that an OS may consist of a number of levels, some of which are loaded
20 from a boot sector, and others of which may be loaded into the system from other files on a disk. It is possible to infect an OS with a virus by either infecting that part of it that resides in the boot sector (with a boot-sector virus) or by infecting the part of it that is
25 loaded from other files (with a file-infector virus), or both. Thus, in order to maintain the integrity of a computer operating system and prevent viruses from infecting it, it is useful and necessary to prevent both boot-sector and file-infector viruses.

30 Work to develop virus protection for computers has often been aimed at PCs and workstations, which are extremely vulnerable to virus infection. The many commercial packages available to combat and/or recover from viral infection attest to the level of effort in
35 this area.

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Unfortunately, computer virus authors produce new versions and strains of virus code far more rapidly than programs can be developed to identify and combat them.

Since viruses are typically recognized by a "signature", i.e., a unique sequence of instructions, new viral code may at times be difficult to identify. Existing signature-based virus detection and eradication programs require knowledge of the signature of a virus in order to detect that virus.

- 10 Current systems employ different strategies to defend against each type of virus. In one of these strategies to protect against boot infectors, first a clean (uninfected) copy of the boot-sector is made and kept on a backup device, e.g., a separate backup disk.
- 15 Subsequent attempts to write to the boot-sector are detected by the anti-viral software in conjunction with the OS and the user is warned of potential problems of viral infection. Since reading from and writing to a disk is a function performed by the OS kernel, it knows
- 20 when a disk is written to and which part of the disk is being written. Anti-virus software can be used to monitor every disk write to catch those that attempt to modify the boot sector. (Similarly, in systems which keep the OS in a particular named file, every attempt to
- 25 modify that file can be caught). At this point, if the boot-sector has been corrupted the user can replace it with a clean copy from the backup disk.

To inhibit file infectors an integrity check, e.g., a checksum is calculated and maintained of all

- 30 executables on the system, so that any subsequent modification may be detected. A checksum is typically an integral value associated with a file that is some function of the contents of the file. In the most common and simple case the checksum of a file is the sum of the
- 35 integer values obtained by considering each byte of data

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in the file as an integer value. Other more complicated schemes of determining a checksum are possible, e.g., the sum of the bytes in the file added to the size of the file in bytes. Whatever the scheme used, a change in the file will almost always cause a corresponding change in the checksum value for that file, thereby giving an indication that the file has been modified. If a file is found with a changed checksum, it is assumed to be infected. It can be removed from the computer system and a clean copy can be restored from backup.

Many viruses use the low-level primitive functions of the OS, e.g., disk reads and writes, to access the hardware. As mentioned above, these viruses can often be caught by anti-viral software that monitors all use of the OS's primitives. To further complicate matters however, some viruses issue machine instructions directly to the hardware, thus avoiding the use of OS primitive functions. Viruses which issue instructions directly to the hardware can bypass software defenses because there is no way that their activities can be monitored. Further, new self-encrypting (stealth) viruses may be extremely difficult to detect, and thus may be overlooked by signature recognition programs.

One approach to the boot integrity problem is to place the entire operating system in read-only memory (ROM) of the computer. However, this approach has disadvantages in that it prevents modifications to boot information, but at the cost of updatability. Any upgrades to the OS require physical access to the hardware and replacement of the ROM chips. It is also the case that as operating systems become more and more sophisticated, they become larger and larger. Their placement in ROM would require larger and larger ROMs. If user authentication is added to the boot program,

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passwords may be difficult to change and operate on a per machine rather than a per user basis.

Some Operating Systems have so-called login programs which require users to enter a password in order to use the system. These login programs, whether stand-alone or integrated with an antiviral program, suffer from the same timing issues as previously mentioned. Also since most PCs provide a means of booting from alternate devices, e.g., a floppy disc drive, login programs can often be trivially defeated.

Summary of the Invention

In general, in one aspect, the invention features reducing the possibility of corruption of critical information required in the operation of a computer, by storing the critical information in a device; communicating authorization information between the device and the computer; and causing the device, in response to the authorization information, to enable the computer to read the critical information stored in the device.

Embodiments of the invention include the following features. The authorization information may be a password entered by a user and verified by the device (by comparison with a pre-stored password for the user); or biometric information (e.g. a fingerprint) about a user. The device may be a pocket-sized card containing the microprocessor and the memory (e.g., a smartcard). The critical information may include boot-sector information used in starting the computer; or executable code; or system data or user data; or file integrity information. The computer may boot itself from the critical information read from the device by executing modified boot code (stored as a BIOS extension) in place of normal boot code.

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The device may pass to the computer secret information shared with the computer (e.g., a host access code); the computer validates the shared secret information. The authorization information may be file
5 signatures for executable code; or a user's cryptographic key.

A communication link between the device and the computer carries the authorization information and the critical information.

10 In general, in another aspect, the invention features initializing a device for use in reducing the possibility of corruption of critical information required in the operation of a computer, by storing the critical information in memory on the device, storing
15 authorization information in memory on the device, and configuring a microprocessor in the device to release the critical information to the computer only after completing an authorization routine based on the authorization information.

20 In general, in another aspect, the invention features a portable intelligent token for use in effecting a secure startup of a host computer. The token includes a housing, a memory within the housing containing information needed for startup of the host
25 computer, and a communication channel for allowing the memory to be accessed externally of the housing.

In embodiments of the invention, the memory also contains a password for authorization, and a processor for comparing the stored password with externally
30 supplied passwords. The memory may store information with respect to multiple host computers.

Among the advantages of the invention are the following.

The invention provides extremely powerful security
35 at relatively low cost, measured both in terms of

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purchase price and setup time. The additional hardware required is nominal, initial setup is one-time only, and upgrades require no hardware access--provided the user has the proper authentication. The invention obviates the need to defend against boot infectors and greatly reduces the risk to selected executables. The invention eliminates the PC's vulnerability to boot infectors, ensures the integrity of selected data, and guarantees the reliability of executables uploaded from the smartcard. Due to the authentication which occurs in the boot sequence, the possibility of sabotage or unauthorized use of the PC is restricted to those users who possess both a properly configured smartcard and the ability to activate it.

Other advantages and features will become apparent from the following description and from the claims.

Description

Fig. 1 is a diagram of a typical computer system using the invention;

Fig. 2 depicts the levels of an operating system;

Fig. 3 shows the layout of a computer disk;

Fig. 4 is a view of the memory of the computer system shown in Fig. 1;

Figs. 5-6 show, schematically, a smartcard and its memory;

Figs. 7-10 are flow diagrams of boot processes.

The invention makes use of so-called intelligent tokens to store a protected copy of the file that is usually stored in a disk boot sector, along with other file integrity data.

Intelligent tokens are a class of small (pocket-sized) computer devices which consist of an integrated circuit (IC) mounted on a transport medium such as plastic. They may also include downsized peripherals necessary for the token's application. Examples of such

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peripherals are keypads, displays, and biometric devices (e.g., thumbprint scanners). The portability of these tokens lends itself to security-sensitive applications.

A subclass of intelligent tokens are IC cards, also known as smartcards. The physical characteristics of smartcards are specified by The International Standards Organization (ISO) (described in International Standard 7816-1, Identification Cards - Integrated Circuit(s) with Contacts - Physical Characteristics, International Standards Organization, 1987). In brief, the standard defines a smartcard as a credit card sized piece of flexible plastic with an IC embedded in the upper left hand side. Communication with the smartcard is accomplished through contacts which overlay the IC (described in International Standard 7816-2, Identification Cards - Integrated Circuit(s) With Contacts - Dimensions and Location of the Contacts, International Standards Organization, 1988). Further, ISO also defines multiple communications protocols for issuing commands to a smartcard (described in International Standard 7816-3, Identification Cards - Integrated Circuit(s) With Contacts - Electronic Signals and Transmission Protocols, International Standards Organization, 1989). While all references to smartcards here refer to ISO standard smartcards, the concepts and applications are valid for intelligent tokens in general.

The capability of a smartcard is defined by its IC. As the name implies, an integrated circuit consists of multiple components combined within a single chip. Some possible components are a microprocessor, non-static random access memory (RAM), read only memory (ROM), electrically programmable read only memory (EPROM), nonvolatile memory (memory which retains its state when current is removed) such as electrically erasable programmable read only memory (EEPROM), and special

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purpose coprocessor(s). The chip designer selects the components as needed and designs the chip mask. The chip mask is burned onto the substrate material, filled with a conductive material, and sealed with contacts protruding.

5 Fig. 5 depicts a typical smartcard 22 with IC 32 which contains a CPU 34 and memory 36. Memory 36 is made up of a ROM 38 and an EEPROM 40.

The current substrate of choice is silicon. Unfortunately silicon, like glass, is not particularly
10 flexible; thus to avoid breakage when the smartcard is bent, the IC is limited to only a few millimeters on a side. The size of the chip correspondingly limits the memory and processing resources which may be placed on it. For example, EEPROM occupies twice the space of ROM
15 while RAM requires twice the space of EEPROM. Another factor is the mortality of the EEPROM used for data storage, which is generally rated for 10,000 write cycles and deemed unreliable after 100,000 write cycles.

Several chip vendors (currently including Intel,
20 Motorola, SGS Thompson, and Hitachi) provide ICs for use in smartcards. In general, these vendors have adapted eight-bit micro-controllers, with clock rates of approximately 4 megahertz (Mhz) for use in smartcards. However, higher performance chips are under development.
25 Hitachi's H8/310 is representative of the capabilities of today's smartcard chips. It provides 256 bytes of RAM, 10 kilobytes (K) of ROM, and 8K of EEPROM. The successor, the H8/510, not yet released, claims a 16-bit 10 Mhz processor, and twice the memory of the H8/310. It
30 is assumed that other vendors have similar chips in various stages of development.

Due to these and other limits imposed by current technology, tokens are often built to application-specific standards. For example, while there is
35 increased security in incorporating peripherals with the

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token, the resulting expense and dimensions of self-contained tokens is often prohibitive. Because of the downsizing required for token-based peripherals, there are also usability issues involved. From a practical perspective, peripherals may be externally provided as long as there is reasonable assurance of the integrity of the hardware and software interface provided. The thickness and bend requirements for smartcards do not currently allow for the incorporation of such peripherals, nor is it currently feasible to provide a constant power supply. Thus, today's smartcards must depend upon externally provided peripherals to supply user input as well as time and date information, and a means to display output. Even if such devices existed for smartcards, it is likely that cost would prohibit their use. For most applications it is more cost effective to provide a single set of high cost input/output (I/O) devices for multiple cards (costing \$15-\$20 each) than to increase smartcard cost by orders of magnitude. This approach has the added benefit of encouraging the proliferation of cardholders.

Smartcards are more than adequate for a variety of applications in the field of computer security (and a number of applications outside the field). The National Institute of Standards and Technology (NIST) has developed the Advanced Secure Access Control System (ASACS) which provides both symmetric (secret key) and asymmetric (public key) cryptographic algorithms on a smartcard (described in An Overview Of The Advanced Smartcard Access Control System, J. Dray and D. Balenson, Computer Security Division/ Computer Systems Laboratory, National Institute of Standards and Technology, Gaithersburg, Maryland). The ASACS utilizes DES (Data Encryption Standard) (described in Data Encryption Standard - FIPS Publication 46-1, National Institute of

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Standards and Technology (formerly NBS), Gaithersburg, Maryland) for login authentication using the 9.26 standard authentication protocol (defined in Financial Institution Sign-on Authentication For Wholesale Financial Systems [DES-based user authentication protocols], ANSI X9.26, X9 Secretariat, American Bankers Association, Washington, D.C.). It further offers a choice of RSA (described in R. L. Rivest, A. Shamir, L. M. Adleman, "A Method for Obtaining Digital Signatures and Public Key Cryptosystems," Communications of the ACM, pp. 120-126, Volume 21, Number 2, February 1978) or DSA (described in "The Digital Signature Standard Proposed by NIST", Communications of the ACM, Volume 35, No. 7, July, 1992, pp. 36-40) for digital signatures.

The ASACS card provides strong security because all secret information is utilized solely within the confines of the card. It is never necessary for a secret or private key to be transferred from the card to a host computer; all cryptographic operations are performed in their entirety on the card. Although the current H8/310 equipped card requires up to 20 seconds to perform sign and verify operations, a new card developed for the National Security Agency (NSA) is capable of performing the same operations in less than a second. The NSA card is equipped with an Intel 8031 processor, a Cylink CY513 modular exponentiator (coprocessor), 512 bytes of RAM and 16 Kbytes of EEPROM. Since both the RSA and DSA algorithms are based on modular exponentiation, it is the Cylink coprocessor which accounts for the NSA card's greatly enhanced performance.

Trusted Information Systems (TIS), a private computer security company, is currently integrating smartcards for use with privacy enhanced computer mail in a product called TISPEM. A user-supplied smartcard is used to store the user's private key and in addition

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provides service calls for digital signatures and encryption so that all operations involving the private key are performed on the card. In this way the private key need never leave the card. Thus, a TISPEM user can
5 sit down at any terminal which has access to the application software (and a smartcard reader) and read encrypted mail and send signed messages without fear of compromising his or her private key.

Referring to Figs. 5 and 6, in the invention, a
10 smartcard's memory 36 contains an propriety operating system and software programs to enforce access control (in ROM 38) together with critical information 42, 44, 46 usually stored in the host's boot-sector, directory, and executables (in EEPROM 40). The amount of memory
15 available on the token will dictate the amount of data which may be stored. In addition, other sensitive or private information 48 may be stored to ensure its integrity.

One aspect of I.B.M. personal computers and their
20 clones is that the computer systems are not all identically configured. Some computer systems may have devices, e.g., display monitors or optical disks, that other systems do not have. Some of these computer systems have slots which can accept addin boards which
25 can be used to enhance the system by, for example increasing its speed or the resolution of its display. In order to overcome the complications introduced by non-uniformity of computer platforms, a set of functions that provide an interface to the low-level input/output (I/O)
30 system is provided. In the I.B.M. PC systems this system is called the Basic Input Output System (BIOS) and resides in the EPROM and is loaded by the boot program before it loads the program from the boot sector.

I.B.M. PCs are expandable and can have new devices
35 attached to them using cards inserted into slots in the

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computer's chassis. A new device or card may need to extend the interface to the low-level I/O system, i.e., to extend the BIOS. To do this it uses a BIOS Extension.

The system takes advantage of the following
5 feature of the PC's boot sequence: after loading the BIOS but before loading the boot sector, the boot program examines each expansion slot in the computer, looking for a BIOS extension. If it finds one it hands over control to that extension. In a typical PC system the BIOS
10 extension would load its functions into the system and then pass control back to the boot program. After checking all extension slots for BIOS extensions the boot program then begins looking in the disk drives for a disk with a boot sector from which to boot.

15 Fig. 7 describes the boot sequence of a PC. When the boot sequence is started 50 (either by cycling the power of the computer or by pressing a particular sequence of keys on the keyboard) the boot program in ROM 28 of the computer system loads the BIOS code 52 into
20 memory 14. This BIOS code allows the program to interact with attached devices. The boot program then examines each slot 54 (by address) in turn to determine if it contains a board with a BIOS extension 56. If the boot program finds a slot with a BIOS extension then it loads
25 and executes the code associated with that BIOS extension 58. After the BIOS extension's code is executed, control is passed back to the boot program to examine the next slot address 54. When all slots have been examined the boot program then tries to find a boot disk, i.e., a disk
30 with a boot sector 60. (I.B.M. PCs are configured to look for a boot disk starting in the floppy drives and then on the hard drives.) Once a boot disk is found, its boot sector is loaded and executed 62.

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A Smartcard-Based Operating System

A prototype of the invention, also referred to herein as The Boot Integrity Token System (BITS), has been developed to provide computer boot integrity and enforce access control for an IBM or compatible system (PC-BITS), although the technology described is applicable to a wide variety of other computer systems.

Referring again to Fig. 1, the basic idea behind BITS is that the host computer system 10 will actually boot itself from a smartcard 22. Since the smartcard 22 can be readily configured to require user authentication prior to data access, it provides an ideal mechanism to secure a host computer. Thus, if critical information required to complete the boot sequence is retrieved from a smartcard, boot integrity may be reasonably assured. The security of the system assumes the physical security of the host either with a tamper-proof or tamper-evident casing, and the security of the smartcard by its design and configuration. If an attacker can gain physical access to the hardware, it is impossible to guarantee system integrity.

Referring to Figs. 1 and 4-6, the PC-BITS prototype consists of an 8-bit addin board 30, a smartcard drive 20 (reader/writer) which mounts in a floppy bay of computer system 10, configuration as well as file signature validation software, and a supply of smartcards. The board 30 contains a special boot PROM which is loaded with a program which interfaces to the smartcard reader. Further, the board is configurable to set an identifier for the host.

Installation and configuration of the host can be accomplished in minutes. The process involves insertion of the addin board and the equivalent of the installation of a floppy drive. Once installed, the computer will not complete the boot sequence without a valid user

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authentication to a properly configured smartcard. The reason for this is that the addin board 30 is a BIOS Extension board. Recall from the discussion above, with reference to Fig. 7, that the boot program loads and
5 executes any and all BIOS extensions 58 before it looks for a boot disk 60. The addin board 30 takes control from the boot program when its BIOS extension is loaded, but it does not return control back to the boot program. Thus, the modified boot process is like that depicted in
10 Fig. 8, where the process of looking for and loading a boot sector does not take place under control of the boot program, but under the control of the modified boot program on the BIOS Extension card.

During system startup, two authentications must be
15 successfully performed to complete the boot sequence. First, the user enters a password which is checked by the smartcard to confirm that the user is authorized to use that card. If successful, the smartcard allows the PC to read the boot-sector and other information from the
20 smart-card memory. To authenticate the smartcard to the host, the card must also make available a secret shared with the host, in this case the configurable host identifier. Table 1 illustrates these transactions. If both the user and card authentication are successful, the
25 boot sequence completes, and control is given to the PC operating system - some or all of which has been retrieved from the smartcard. The user may then proceed to utilize the PC in the usual fashion, uploading additional information (i.e., applications or application
30 integrity information) from the smartcard as needed.

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Step	Action	Implementation
0	Insert card and power up the host	Apply power and reset card
1	Authenticate user and present data to the smartcard	Present user password to the smartcard
2	Authenticate the card to the host	Host reads shared secret from the smartcard
3	Upload boot information	Host reads boot-sector from the smartcard
4	Integrity check host-resident boot files and complete boot sequence if successful	Host computes file-checksum which the smartcard encrypts to form a signature; this value is compared with the signature stored on the card

Table 1: PC-BITS System Startup

The card is expected to contain critical data such as digital file signatures for system executables and the user's cryptographic keys. Comparing executable file signatures with those stored on the smartcard provides a virus detection mechanism which is difficult to defeat. This approach is consistent with a recent trend to validate file integrity rather than solely scan for known virus signatures.

Refer now to Figs. 9-10, which show the control flow of the modified boot sequence from the point of view of the computer system and the smartcard respectively. The flow diagram in Fig. 9 shows the control flow of the modified boot program loaded from the BIOS Extension addin card in step 58 (Fig. 8) of the original boot sequence. Fig. 10 shows the processing that occurs (during the boot sequence) on the CPU 34 of the smartcard while it is in the smartcard reader 20.

The modified boot program (the BIOS extension) prompts the user for a password 60 on display 18. The

- 21 -

password is read 62 from keyboard 16 and sent to the smartcard 22. At the same time, the smartcard is waiting for a password 92. When the smartcard 22 gets a password 94 from the computer system 10 it validates the password 96 using whatever builtin validation scheme comes with the smartcard. If the password is invalid then the smartcard 22 returns a "NACK" signal 100 to the computer system 10, disallows reading of its data 102 and continues to wait for another password 92. (In some systems a count is kept of the number of times an invalid password is entered, with only a limited number of failed attempts allowed before the system shuts down and requires operator or administrator intervention.) If the password is valid then the smartcard 22 returns an "ACK" signal 98 to the computer system 10 and allows reading of the data in its memory and files 104.

The computer system 10 waits for the response 66 from the smartcard 22 and then bases its processing on the returned result 68. If the password was invalid (i.e., the smartcard returned an "NACK" signal) then the user is once again prompted for a password 60 (recall again the discussion above about limiting the number of attempts.) If the password is valid the user has been authenticated to the smartcard and now the computer system attempts to authenticate the card for the system. It does this (in step 70) by reading a host access code 46 from EEPROM 40 of the smartcard 22. (The host access code is one of the items of data put on the smartcard by the system administrator during system configuration.) The host access code 46 from the smartcard is compared to the one that the system has stored about itself 72. If they are unequal then this smartcard 22 is not allowed for this host computer system 10 and the boot process is terminated 74. (Note that this termination ends the entire boot process - the boot program does not then try

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to boot from a disk). If the check at step 72 finds the codes to be equal then the card is authenticated to the host and the boot sector 42 from EEPROM 40 of smartcard 22 is read (step 76) into memory 14 of computer system 5 10.

Recall that, because of the limited size of the memory on smartcards today, it is not yet possible to store all the information and files for an OS the size of, e.g., MS-DOS on a smartcard. Therefore the other 10 files will have to be read from a disk or other storage device. It is, however, still possible to ensure their integrity by the use of integrity information, e.g., checksums for the files, stored on the smartcard (by a system administrator).

15 In step 78 the BIOS Extension program reads the file integrity information 44 from the EEPROM 40 of the smartcard 22. Then, for each file whose integrity is required, e.g., IO.SYS, etc, the integrity information for that file is validated (step 80). If the OS files 20 are found to be invalid 82 then an error is reported 84 to the user on display 18. If the error is considered to be severe 88 then the boot process terminates 90. (The determination of what constitutes "severe" is made in advance by the system administrator based on the security 25 requirements of the system. In some systems no file changes are allowed, in others some specific files may be modified, but not others.)

If the file integrity information is valid (or the error is not considered severe) then the boot sector that 30 was loaded from the smartcard (in step 76) is executed 86. At this point the boot process will continue as if the boot sector had been loaded from a disk (as in the unsafe system).

In the BITS system, cards are configured and 35 issued by a security officer using the software provided

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- the current prototype is written in C to improve portability.

Configuration entails the loading onto the smartcard of the boot sector 42 as well as digital
5 signatures for boot files stored on the host 44. At the time of issue, it is necessary to specify the machine or set of machines 46 that the user to whom the card is being issued will be granted access so that a host key may be loaded. File integrity information and portions
10 of the host operating system are also loaded onto the smartcard at this time 44. All data is read protected by the user's authentication (e.g., cannot be read unless the user password is presented correctly), and write protected by the security officer authentication. This
15 arrangement (depicted in Table 2) prevents users from inadvertently or deliberately corrupting critical data on the smartcard.

Smartcards may be issued on a per host, per group, or per site basis depending on the level of security
20 desired. Since the secret shared by the host and card is configurable on the host, it is possible to issue smartcards in a one-to-one, many-to-one, or many-to-many fashion. A one-to-one mapping of users to hosts corresponds to securing a machine for a single user.
25 Analogously, many-to-one allows the sharing of a single machine, and many-to-many allows for the sharing of multiple machines among an explicit set of users. One-to-many is a possible, but usually wasteful, mapping of computer resources.

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Step	Action	Implementation
0	Security officer creates user and security officer accounts on card	Present manufacturer password and load user-specified secret codes for accounts.
1	Load boot-sector onto card	Create a file readable under the user password and writable under the security officer password and write the partition boot record.
2	Compute and load signatures for selected files	For each file compute a hash which is encrypted by the card. This signature together with the file name is stored on the card.
5 3	Load host authentication information	Create a file readable under the user password and writable under the security officer password and write a secret to be shared with the host.

Table 2: BITS Smartcard Configuration

The effectiveness of BITS is limited by the feasibility of storing all boot-relevant information on a smartcard. To the extent this is possible, boot integrity will be maintained. BITS is not a virus checker, however, for those files whose signatures are stored on the smartcard, it is possible to detect the modification of the file on the host system. Thus the user may be notified that an executable is suspect before it is run. In general BITS will provide enhanced computer security by utilizing the secure storage and processing capabilities inherent to the smartcard.

From a security perspective, the less that a user depends upon from a shared environment, the better. Any shared writable executable may potentially contain malicious code. Fortunately, advances in technology are likely to permit the storage of entire operating systems

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as well as utilities on a smartcard, thus obviating the necessity of sharing executables altogether.

Smartcards themselves may also be made more secure. Currently, authentication to the smartcard is limited to user-supplied passwords. In most systems, three consecutive false presentations results in the smartcard account being disabled. However, if biometric authentication (e.g., fingerprint checks or retinal scans) is incorporated into the card, it will be possible to achieve higher assurance in user authentication.

To date, the size requirements of smartcards have imposed the greatest limitation upon their utility; the current state of the art is a 1.0 micron resolution in the burning of chip masks. However, SGS Thompson and Phillips recently announced the development of 0.7 micron technology as well as plans for a 0.5 micron technology. Regardless of these advances, the chips themselves are still currently limited to a few millimeters on a side due to the brittle nature of the silicon substrate from which they are made. A flexible substrate might allow chips which occupy the entire surface of the smartcard resulting in an exponential gain in computing resources.

A smartcard with this capability would result in a truly portable (wallet-sized) personal computer which could be made widely available at relatively low cost. In this type of computing environment only the bulky human interface need be shared. A computing station might consist of a monitor, a keyboard, a printer, and a smartcard interface. The user could walk up to the computing station, supply the CPU and data storage, and begin work.

The implications of this technology are impressive. The existence of instant PC access for millions regardless of location would greatly enhance the utility of computers. The ability to use the same

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environment wherever one chooses to work would eliminate time spent customizing and increase productivity. The security provided by smartcards may also result in increased security for sensitive data by decreasing the
5 likelihood of compromise or loss.

Because of the mode in which the invention is used, it might be wrongly compared with a boot from floppy disk. While it is true that inserting a smartcard is similar to inserting a floppy, the interaction during
10 the boot sequence is entirely different. The smartcard-based system incorporates two separate authentications, user to card and card to host, which are entirely absent from the floppy boot. Further, the integrity of the boot
15 information on a floppy is protected only by an easily removed write-protect-tab; while the smartcard requires the authentication of the security officer in order to update boot information. One may also note the ease of carrying a smartcard as compared with a floppy disk.

The invention has been installed and tested on a
20 desktop computer. However, the system is easily generalizable to any computing environment including mainframe, microcomputer, workstation, or laptop. The intelligent token of choice for this embodiment is a smartcard. The reason is that ISO Standard smartcards
25 are expected to be the most ubiquitous and consequently the least expensive form of intelligent token.

Appendix A, incorporated by reference, is a source code listing of the BIOS Extension code loaded onto the memory of the addin board (as described above) written in
30 8088 Assembly language. This code may be assembled using a Borland Turbo Assembler (TASM™) and linked using a Borland Turbo Linker (TLINK™), and run on a AT Bus (ISA compatible) computer running a DOS compatible OS. Appendix A contains material which is subject to
35 copyright protection. The owner has no objection to

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Appendix A

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```

;dosbits.asm      Paul C. Clark
;                  BOOT INTEGRITY TOKEN SYSTEM - DOS Version
5 ;                  BIOS Extension for DOS smartcard boot
;                  Version 1

;      Useful Defines
ACK          EQU      60h
ETX          EQU      03h
10 NAK        EQU      000E0h
COM1_CTL_REG EQU      003FCh
COM1_DATA_REG EQU      003F8h
COM1_STAT_REG EQU      003FDh
STACKAREA   EQU      06000h
15 SCRATCHAREA EQU      07000h
PBRAddress  EQU      07C00h
PWDAddress  EQU      0C007h

;-----
20 Cseg          Segment Para Public 'Code'
                        Assume CS:Cseg
                        Org 03h                      ;Code starts
after extension

                        ;signature and length
                        ;Save stack
25      Mov      BX,SP
      Mov      CX,SS
      Push     BX
      Push     CX
      Mov      AX,STACKAREA      ;Set up new stack
      Mov      SS,AX
30      Mov      SP,0000h
      Mov      AX,SCRATCHAREA    ;Set scratch area
      Mov      ES,AX
      Push     CS                ;Data seg = Code
seg for small model
35      Pop      DS
      Sti                     ;Allow breaks
      Cld                    ;Set direction to
increment

      Call     Main

40      Pop      CX                ;Restore original
stack
      Pop      BX
      Mov      SS,CX

```

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```

                                Mov     SP,BX
                                Jmp      Int19Hdl          ;Execute the PBR

                                Abort    Label Near
                                DB        0CBh            ;Far return
5  opcode                      Mov     AH,4Ch            ; Return
    ; control to DOS
    ;                      INT     21h

    ;-----
10 ;Identify BIOS extension
    ;-----
                                DB        'ROM BIOS Extension for DOS BITS '
                                DB        'Version 1 '

    ;-----
15 ;Main Program
    ;-----
Main      Proc      Near

                                Call     InitPort          ;Initialize COM
                                port
                                Call     ClrScr             ;Clear screen
20                                Call     DrawBox           ;Draw the frame
                                for dialog

                                Mov     DX,071Ah
                                Mov     SI,offset STitle    ;Display title
25                                Call     StrScr
                                Mov     DX,081Eh
                                Mov     SI,offset SSTitle   ;Display
                                subtitle

                                Call     StrScr
30                                Mov     DX,0A1Dh
                                Mov     SI,offset InsrtCrd  ;Prompt user for
                                card

                                Call     StrScr
35                                Call     WaitCard          ;Wait until card
                                is inserted
                                Call     GetPwd             ;Get and present
                                password

                                Mov     AX,SCRATCHAREA
                                Mov     ES,AX
40                                Call     ReadPbr           ;Read and
                                install PBR from card

                                Mov     DX,0C1Ah

```

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```

message      Mov      SI,offset Erase      ;Erase load
              Call     StrScr
5  file checking  Mov     DX,0C1Ah          ;Notify user of
              Mov     SI,offset FileChk
              Call     StrScr
              Call     ChkIO              ;Check IO.SYS
10 integrity     Call     ChkMSDOS         ;Check MSDOS.SYS
              Call     ChkCMD             ;Check
              Call     ChkCFGSYS         ;Check
15 CONFIG.SYS integrity
              Mov     DX,0C1Ah
              Mov     SI,offset Erase      ;Erase file
              Call     StrScr
20              Call     ClrScr
              Mov     SI,offset PowerOff   ;Remove power
              Call     CReaderCom
              ;PC hangs part way through boot process using this
25 technique! Needs fix!
              ;      Xor      AX,AX          ;Replace INT
19 handler with
              ;      Mov     DS,AX          ;address of
PBR
30 ;      Lea     AX,PBRAddress        ;Jump to
where the PBR is
              ;      Mov     DS:[0064],AX
              ;      Push    CS
              ;      Pop     AX
35 ;      Mov     DS:[0066],AX
              ;      Int     19
              Ret
Main          Endp

;-----
40 ;Interrupt 19 (Warm Boot) Handler
;      - execute PBR loaded from card.
;-----
Int19Hdl      Proc      Far
              Sti

```


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```

0000:7C00      DB      0EAh,00h,7Ch,00h,00h      ;Far JMP to
Int19Hdl      EndP

;-----
5  ;Initialize COM1: 9600,N,8,1
;-----
InitPort      Proc      Near
               Push     AX
               Push     DX
10
               Mov      AH,00                      ;Interrupt 14
               service 0
               Mov      AL,11100011b              ;9600 baud, no
               parity, 8 bit data
15             Mov      DX,0000                    ;COM1:
               Int      14h
               Pop      DX
               Pop      AX
20             Ret
InitPort      Endp

;-----
;Wait for card to be inserted
;-----
25 WaitCard      Proc      Near
               Cli
               WaitLoop      Label      Near
               Push     DS
30             Mov      SI,offset InitRdr          ;Initizlize
               reader
               Call     CReaderCom
               Mov      SI,offset StCrdTp          ;Set card type
               Call     CReaderCom
35             Mov      SI,offset InitRdr          ;Reset card
               Call     CReaderCom
               Mov      SI,offset PowerOn          ;Apply power
               to card
               Call     CReaderCom
40             Mov      SI,0001h
               Mov      BX,SCRATCHAREA
               Mov      DS,BX
               Lodsb
               Cmp      AL,04h                      ;If return
45             code is 4 bytes,
               Pop      DS                          ;Card isn't
               there!

```

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```

                                Jz      WaitLoop      ;Otherwise
something is there...

                                Sti
5  WaitCard                    Ret
                                Endp

;-----
;Get password from user and present to card
;-----
10 GetPwd                      Proc      Near
                                Push     AX
                                Push     CX
                                Push     DS
                                Push     DI
15 PwdLoop                    Label     Near
                                Mov       CX,00h      ;Initialize
                                character count
                                Mov       DX,0A1Ah    ;Erase previous
                                message
20                               Mov       SI,offset Erase
                                Call      StrScr
                                Mov       DX,0A1Ah
                                Mov       SI,offset PwdPrmpt ;Display
                                password prompt
25                               Call      StrScr
                                Mov       DI,PWDAddress

                                ReadLoop    Label     Near

                                Mov       SI,offset KbdStat ;Display
                                keyboard status label
30                               Mov       DX,0101h
                                Call      StrScr
                                Mov       AH,01h      ;Check
                                keyboard status
                                Int       16h
35                               Call      DispStat    ;Display ;
                                Keyboard Status
                                Jz        ReadLoop      ;Loop on
                                empty buffer

                                Mov       DX,CX        ;Put the cursor in
40 the right place
                                Add       DX,0A24h
                                Call      CurPos

                                Mov       AH,0h
                                Int       16h          ;Read character
45 from keyboard

```

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```

                                Cmp      AL,08h                ;Check for
<BACKSPACE>
                                Je        EraseChar
                                Cmp      AL,0Dh                ;Check for
5  <RETURN>
                                Je        SpaceFill
                                Cmp      AL,1bh                ;check for <ESC>
                                Je        SpaceFill
                                Cmp      CX,08h                ;Length cannot
10 exceed eight
                                Jge      Beep
                                Stosb
                                presentation str                ;Store as part of
                                Inc      CX                    ;Increment
15 character count
                                Mov      AL,'X'
                                Call     DisplayChar
                                Jump     ReadLoop
                                EraseChar Label Near          ;Process a
20 BACKSPACE
                                Cmp      CX,00h                ;Is backspace all
                                Je        Beep                  ;if no chars to
                                delete goto read loop
25                                Dec      DI                    ;Remove character
                                before backspace
                                Dec      CX                    ;Decrement char
                                count
                                Call     DisplayChar
30                                Mov      AL,' '
                                Call     DisplayChar
                                Mov      AL,08h
                                Call     DisplayChar
                                Jump     ReadLoop
35 Beep
    continue
                                Label    Near                  ;Ring the bell and
                                Mov      AL,07h
                                Call     DisplayChar
                                Jump     ReadLoop
40 SpaceFill Label Near          ;User has pressed
    RETURN or ESC
                                Mov      AL,' '
                                spaces
                                padloop label near            ;Pad out pwd with
45                                Cmp      CX,08h
                                Jge      Presentpw              ;After space
                                padding, send pw

```

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```

                                Stosb
                                Inc    CX
                                Jump    padloop

Presentpw Label Near
5 ;Jump CodeOK
    Mov    AX,0C000h          ;Fill-in rest of
    present code cmd
    Mov    DI,AX
    Mov    AL,0Eh
10    Stosb
    Mov    AX,000DAh
    Stosw
    Mov    AX,0020h
    Stosw
15    Mov    AX,0804h
    StoSw

    Mov    SI,0C000h          ;Present the code to
20 the reader
    Mov    AX,SCRATCHAREA
    Mov    DS,AX
    Call   CReaderCom

    Mov    SI,0003            ;Look at the card
25 response string
    Lodsb
    Cmp    AL,90h             ;90h = code ok
    Je     CodeOK
    Lodsb
30 (!)    Cmp    AL,40h        ;9840h = card locked
    Je     CardLock

    Mov    DX,0C1Ah
35    Mov    SI,offset BadPass
    Call   StrScr
    Jump   PwdLoop           ;Give it another try

CardLock Label Near          ;Card is locked...
40    Mov    DX,0A1Ah
    Mov    SI,offset Erase
    Call   StrScr
    Mov    DX,0C1Ah
    Mov    SI,offset Erase
    Call   StrScr
45    Mov    DX,0B20h
    Mov    SI,offset CdLck    ;Inform user
    Call   StrScr
    Mov    DX,0C1Ah
    Mov    SI,offset CdLck2

```

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```

                Call    StrScr
                Mov     SI,offset PowerOff
                Call    CReaderCom
5  LockLoop     Label   Near
                Jump    LockLoop           ;Hang in infinite
                loop
                CodeOK  Label   Near           ;Presentation was
                OK...
10              Mov     DX,0C1Ah
                Mov     SI,offset Erase
                Call    StrScr
                Mov     DX,0C1Ah
                Mov     SI,offset Corrcrct ;Inform user
                Call    StrScr
15              Pop     DI
                Pop     DS
                Pop     CX           ;Cleanup and return
                Pop     AX
                Ret
20 GetPwd      Endp

```

```

;-----
;Load partition boot record from card
;-----
25 ReadPBR     Proc     Near
                Push    DS
                Mov     SI,offset SelPbrFl   ;Select the
                Call    CReaderCom
30              Mov     AX,0C000h           ;Form command
                at 7000:C000
                Mov     DI,AX
                Mov     AX,0DB06h           ;Store command
35 bytes      Stosw
                Mov     AX,0B200h
                Stosw
                Xor     AX,AX
40              Stosw
                Mov     AL,34h
                Stosb
                Xor     DX,DX           ;Init no.
45 bytes read Mov     BH,01h
                RFLoop  Label   Near

```

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```

                    Mov     AX,0C004h
                    Mov     DI,AX
                    Mov     AX,DX
                    Mov     CL,04h
5                   Div     CL
                    Stosb
                    Cmp     BH,0Ah
                    Jne     SendRdCmd
                    Inc     DI
10                  Mov     AL,2Ch
                    Stosb
SendRdCmd Label     Near
                    Mov     SI,0C000h
                    Mov     AX,SCRATCHAREA
15                  Mov     DS,AX
                    Call    CReaderCom
                    Push    ES
                    Xor     AX,AX
                    Mov     ES,AX                                ;Destination
20 segment 0000
                    Mov     SI,0003                                ;Skip header
                    bytes
                    Mov     AX,PBRAddress
                    Add     AX,DX
25                  Mov     DI,AX
                    Add     DX,0034h
                    Mov     CX,001Ah
                    Cmp     BH,0Ah
                    Jne     DoCopy
30                  Mov     CX,0016h
DoCopy Label     Near
                    Repz
                    Movsw                                ;Copy word at
a time
35                  Pop     ES
                    Inc     BH
                    Cmp     BH,0Bh
                    Jne     RFLoop
40                  Pop     DS
ReadPBR Ret
                    Endp

;-----
;Check integrity of IO.SYS
;-----
45 ChkIO Proc Near
                    Mov     DX,0C2Ah                                ;Display filename
                    Call    CurPos
                    Mov     SI,offset File1

```

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```

                Call    StrScr
                Push    BX
                Mov     BX,0004h           ;Simple delay for
simulation
5              Call    Delay
                Pop     BX
                Ret
                Endp
                ChkIO

;-----
10 ;Check integrity of MSDOS.SYS
;-----
                ChkMSDOS Proc Near
                Mov     DX,0C2Ah           ;Erase previous
15 filename
                Mov     SI,offset SErase
                Call    StrScr
                Mov     DX,0C2Ah           ;Display filename
                Mov     SI,offset File2
20              Call    StrScr
                Push    BX
                Mov     BX,0004h           ;Simple delay for
simulation
                Call    Delay
25              Pop     BX
                Ret
                Endp
                ChkMSDOS

;-----
30 ;Check integrity of COMMAND.COM
;-----
                ChkCMD Proc Near
                Mov     DX,0C2Ah           ;Erase previous
35 filename
                Mov     SI,offset SErase
                Call    StrScr
                Mov     DX,0C2Ah           ;Display filename
                Mov     SI,offset File3
                Call    StrScr
40              Push    BX
                Mov     BX,0004h           ;Simple delay for
simulation
                Call    Delay
45              Pop     BX
                Ret
                Endp
                ChkCMD

```

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```

;-----
;Check integrity of CONFIG.SYS
;-----
5  ChkCFGSYS  Proc      Near
      filename      Mov      DX,0C2Ah          ;Erase previous
      Mov      SI,offset SErase
      Call     StrScr
10      Mov      DX,0C2Ah          ;Display filename
      Mov      SI,offset File4
      Call     StrScr
      Push     BX
      Mov      BX,0004h          ;Simple delay for
15  simulation    Call     Delay
      Pop      BX
      Ret
20  ChkCFGSYS  Endp

;-----
;Busy wait:
;      - duration passed in BX
;-----
25  Delay  Proc Near
      Push BX
      Push CX
      DLoop0 Label      Near
      Mov  CX,0000
30  DLoop1 Label      Near
      Inc  CX
      Cmp  CX,0FFFFh
      Jne  DLoop1
      Dec  BX
35      Jnz  DLoop0
      Pop  CX
      Pop  BX
      Ret
      Delay Endp

40 ;-----
;Transmit byte to COM1:
;      - byte passed on stack
;-----
45  SendByte  Proc      Near
      Push     BP
      Mov      BP,SP
      Push     AX
      Push     DX

```

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```

        Mov     DX,0000
SendDly  Label   Near
overrun                ;Delay to prevent
5          Inc     DX
        Cmp     DX,00FFh
        Jnz     SendDly

        Mov     DX,COM1_CTL_REG ;Indicate send
10         Mov     AL,0Bh
        Out     DX,AL

        Mov     DX,COM1_DATA_REG ;Output byte to port
        Mov     AL,byte ptr [BP+4]
        Out     DX,AL
15
        Pop     DX
        Pop     AX
        Pop     BP
        Ret
20 SendByte Endp

```

```

;-----
;Transmit ASCII representation of byte to COM1:
; - byte passed on stack
;-----
25 ASendByte Proc Near
        Push    BP
        Mov     BP,SP
        Push    AX
        Push    DX
30        Push    CX

        Mov     AL,byte ptr [BP+4] ;Get byte
        Mov     AH,00
        Mov     CL,04h
        Shr     AX,CL                ;Arith shift right

35        Cmp     AX,0Ah                ;Result > 10
        Jge     HAlpha                ;Yes, calc ASCII
        Jge     HAlpha                ;Yes, calc ASCII
        Add     AL,30h                ;No, calc ASCII
40        Add     AL,30h                ;No, calc ASCII
        Jmp     HSend
        HAlpha  Label Near
        Add     AL,37h                ;Calc ASCII for
        letter
45 Hsend      Label Near
        Push    AX

```

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```

        calculated byte Call SendByte          ;Send out
        Add            SP,02h

5      Mov            AL,byte ptr [BP+4]
        And            AX,000Fh                ;Mask out high
        nibble
        Cmp            AX,0Ah                  ;Result > 10
        (A..F) ?
10     Jge            LAlpha                    ;Yes, calc ASCII
        for letter
        Add            AL,30h                  ;No, calc ASCII
        for number
        Jmp            LSend
15     LAlpha        Label Near
        Add            AL,37h                  ;Calc ASCII for
        letter
        Lsend        Label Near
        Push          AX
20     Call            SendByte                ;Send out
        calculated byte
        Add            SP,02h

25     Pop            CX
        Pop            DX
        Pop            AX
        Pop            BP
        Ret
ASendByte Endp

30     ;-----
        ;Get byte from COM1:
        ;      -byte returned in AL
        ;-----
RcvByte Proc Near
35     Push          DX

        Mov            DX,COM1_STAT_REG ;Wait for receive
        ready
        GetByte       Label Near
        In             AL,DX
40     And            AL,01h
        Jz             GetByte

        Mov            DX,COM1_DATA_REG ;Get byte
        In             AL,DX

45     Pop            DX
        Ret
RcvByte Endp

```

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```

;-----
;Get byte from COM1: converting from ASCII representation
;to byte
;      -byte returned in AL
5 ;      -ETX returns 01 in AH, 00 otherwise
;-----
ARcvByte    Proc    Near
             Push    BX
             Push    CX
10
             Call    RcvByte    ;Get a byte from
port                                     ;
             Cmp     AL,ETX      ;Is it ETX?
             Je      RcvEtx
15
             Cmp     AL,41h      ;Not ETX, convert to
high nibble
             Jge     HNumCvt
             Sub     AL,30h
20 HNumCvt    Label   Near
             Sub     AL,37h
             RcvLow   Label   Near
25 in BL      Mov     BL,AL      ;Store high nibble
             Call    RcvByte    ;Get another byte
from port                                     ;
             Cmp     AL,41h      ;Convert to low
nibble
30             Jge     LNumCvt
             Sub     AL,30h
             Jmp     Combine
LNumCvt      Label   Near
             Sub     AL,37h
35 Combine    Label   Near
             Mov     CL,04
             Shl     BL,CL
             Or      AL,BL      ;Combine h/l nibbles
40 into byte
             Mov     AH,00
             Jmp     RcvDone
RcvEtx       Label   Near
             Mov     AH,01      ;ETX, set AH = 1
45 RcvDone    Label   Near
             Pop     CX
             Pop     BX
             Ret

```

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```

ARcvByte Endp

;-----
;Send NAK to reader/writer (request retransmission)
;-----
5 SendNAK Proc Near
          Push AX

          Mov AL,NAK ;Transmit NAK
          Push AX
          Call ASendByte
10 Add SP,02h

          Mov AL,00 ;Command length is 0
          Push AX
          Call ASendByte
15 Add SP,02h

          Mov AL,NAK ;CRC is just NAK
byte
          Push AX
20 Call ASendByte
          Add SP,02h

          Mov AX,ETX ;Transmit ETX
          Push AX
25 Call SendByte
          Add SP,02h

          Pop AX
          Ret
30 SendNAK Endp

;-----
;Send command to reader/writer
; -check response for NAK and retransmit if
; necessary
35 ; -pointer to string passed in DS:SI
;-----
CReaderCom Proc Near
          Push AX
          Push BX
40 Push CX
          Push DX

          CommandLoop Label Near
          Push DS
          Push SI
45 Call ReaderCom ;Send reader/writer
command

```

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```

response      Call    CGetResp      ;Get reader/writer
               Push    ES
               Pop     DS
5             Mov     SI,0000
               Lodsb                    ;Look at first byte
of response
               Cmp     AL,NAK          ;NAK? message not
received properly
10            Jne     RecvOK          ;Not NAK, message
recieved OK
               Pop     SI
               Pop     DS
               Jump    CommandLoop    ;Try again

15 RecvOK      Label   Near
               Pop     SI
               Pop     DS
               Pop     DX
               Pop     CX
20            Pop     BX
               Pop     AX
               Ret
CReaderCom Endp

;-----
25 ;Send command to reader/writer
;   -pointer to string passed in DS:SI
;-----
ReaderCom Proc    Near
30      Mov     AL,ACK                ;Transmit ACK
      Mov     BL,AL                  ;Store for CRC
      Push    AX
      Call    ASendByte
      Add     SP,02h

35      Lodsb                    ;Load command length
      Xor     BL,AL                ;Compute CRC
      Push    AX
      Call    AsendByte            ;Transmit command
length
40      Add     SP,02h

      Mov     CL,AL                ;Loop on command
length
45      Mov     DL,00
      Label   Near
      Lodsb                    ;Get next command
byte
      Xor     BL,AL                ;Compute CRC

```

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```

byte      Push    AX
          Call    ASendByte      ;Transmit command

5         Add     SP,02h
          Inc     DL
          Cmp     DL,CL
          Jnz     ComLoop

10 CRC     Push    BX              ;Transmit computed
          Call    ASendByte
          Add     SP,02h

15         Mov     AL,ETX          ;Transmit ETX
          Push    AX
          Call    SendByte
          Add     SP,02h

20 ReaderCom Ret
          Endp

;-----
;Get response from reader/writer
; - checks response CRC and requests
; retransmission if necessary
25 ;-----
CGetResp Proc Near

RespLoop Label Near
          Mov     DI,0000          ;Initialize
destination ptr
30         Call    GetResp        ;Get the response
string
          Cmp     AL,00
          Jz      RespDone        ;No error, we're
finished
35         Call    SendNAK        ;Error in response,
request retrans
          Jump    RespLoop

RespDone Label Near
          Ret
40 CGetResp Endp

;-----
;Get a response string from reader/writer
; -response string stored starting at ES:DI
;-----
45 GetResp Proc Near

CharLoop Label Near

```

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```

                    Mov     BL,00                ;Initialize for CRC
                    Call    ARcvByte             ;Recieve byte
                    Stosb
                    Xor     BL,AL                ;Calculate CRC
5                   Cmp     AH,01                ;Repeat until ETX
                    Jnz     CharLoop

                    Xor     BL,ETX              ;Remove ETX from CRC
10 response       Dec     DI                    ;Get CRC from
                    Dec     DI
                    Lodsb
                    Xor     BL,AL                ;Remove CRC from CRC

15 calculated     Cmp     AL,BL                ;Compare with
                    Jz      RespOK
                    Mov     AL,01              ;Return AL=01 if
20 error         Ret

                    RespOK   Label    Near
                    Mov     AL,00              ;Return AL=00 if no
                    error
                    Ret
25 GetResp       Endp

;-----
;Display Contents of AX Register
;-----
DispStat Proc     Near
30             Push CX                ;Save registers
                    Push BX
                    Mov     CX,0004h        ;Shift by one nibble
                    Mov     BX,AX           ;Save AX in BX

                    Mov     AL,AH
35             Shr     AL,CL
                    Call DispNibble

                    Mov     AX,BX           ;Reset AX
                    Mov     AL,AH
                    Call DispNibble

40             Mov     AX,BX           ;Reset AX
                    Shr     AL,CL
                    Call DispNibble

                    Mov     AX,BX           ;Reset AX
                    Call DispNibble

```

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```

Mov  AX,BX          ;Reset AX
Pop  BX
Pop  CX
Ret
5  DispStat  Endp

;-----
;Display character and advance cursor
;      -character to be displayed is passed in AL
;-----
10  DisplayChar  Proc      Near
      Push      AX          ;Save contents of AX
      Push      BX          ;Save contents of BX
      Push      CX          ;Save character count
      Mov       AH,0eh      ;Display X's this
15  should go away)  Mov     BH,00h      ;Select video page
      0
      Mov       CX,01
      Int       10h          ;Echo character
20  count          Pop      CX          ;Restore CX to character
      Pop       BX          ;Restore BX
      Pop       AX          ;Restore AX
      Ret
25  DisplayChar  Endp

;-----
;Display nibble - character to be displayed is
;      passed in the lower nibble of AL
;-----
30  DispNibble   Proc      Near
      Push      AX          ;Save contents of AX
      And       AL,0Fh      ;Mask AL
      Cmp       AL,0Ah
      Jge       letter      ;Display A-F not digit
35  Add         AL,'0'
      Call      DisplayChar
      Pop       AX          ;Restore AX
      Ret
      letter      Label     Near
40  Sub         AL,0Ah
      Add       AL,'A'
      Call      DisplayChar
      Pop       AX          ;Restore AX
      Ret
45  DispNibble   Endp

;-----
;Send string to screen
;      -pointer to string passed in DS:SI

```

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```

;      -location on screen passed in DX (row,col)
;-----
StrScr      Proc      Near
5           Push      AX
           Push      BX
           Push      CX

           Mov      AH,09      ;Interrupt 10
           service 9
           Mov      BH,00      ;Video page 0
10          Lods      BH
           Mov      BL,AL      ;Load attribute
           byte
           Mov      CX,0001    ;Only display
           one of each char
15          Scrloop      Label Near
           Call      CurPos    ;Move cursor
           Lods      CurPos
           Or        AL,AL     ;Our end of
           string byte?
20          Jz        ScrDone   ;If so, we're
           done...
           Int       10h       ;Otherwise
           display character
           Inc       DX        ;Increment
25          cursor position
           Jmp        ScrLoop   ;Repeat with
           next character
           ScrDone      Label Near
30          Pop       CX
           Pop       BX
           Pop       AX
           Ret
StrScr      Endp

35          ;-----
           ;Draw box frame for dialog
           ;-----
DrawBox      Proc      Near
40          Mov      DX,0517h
           Call      CurPos
           Mov      AH,09      ;Service 9
           Mov      BH,00      ;Primary video page
           Mov      BL,07      ;Character attribute

           Mov      CX,0001    ;Display only one
45          Mov      AL,0C9h    ;Upper left corner
           Int       10h

           Mov      DX,0518h    ;Top bar

```

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```

      Call    CurPos
      Mov     AL,0CDh
      Mov     CX,001Fh
      Int     10h

5      Mov     DX,0537h           ;Upper right corner
      Call    CurPos
      Mov     AL,0BBh
      Mov     CX,0001
      Int     10h

10     Mov     DX,0E17h           ;Lower left corner

      Call    CurPos
15     Mov     AL,0C8h
      Int     10h

      Mov     DX,0E18h           ;Bottom bar
      Call    CurPos
20     Mov     AL,0CDh
      Mov     CX,001Fh
      Int     10h

      Mov     DX,0E37h           ;Lower right corner
      Call    CurPos
25     Mov     AL,0BCh
      Mov     CX,0001
      Int     10h

      Mov     DX,0617h           ;Left side
30 LSide  Mov     AL,0BAh
      Label   Near
      Call    CurPos
      Int     10h
      Add     DX,0100h
35     Cmp     DX,0E17h
      Jne     LSide

      Mov     DX,0637h           ;Right side
      RSide   Label   Near
      Call    CurPos
40     Int     10h
      Add     DX,0100h
      Cmp     DX,0E37h
      Jne     RSide
      Ret
DrawBox Endp

45 ;-----
;Clear screen
;-----

```

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```

      ClrScr      Proc      Near
                   Push      AX
                   Push      BX
5                   Push      CX
                   Push      DX

                   Mov      DX,0000h      ;Home cursor
                   Call     CurPos

10  spaces      Mov      AH,09h      ;Fill screen with

                   Mov      CX,0800h
                   Mov      AL,020h
                   Mov      BH,00h
15                   Mov      BL,07h
                   Int      10h

                   Mov      DX,0000      ;Home cursor yet
      again      Call     CurPos

20                   Pop      DX
                   Pop      CX
                   Pop      BX
                   Pop      AX
                   Ret

25  ClrScr      Endp

;-----
;Set cursor position
;      -cursor row passed in DH
;      -cursor column passed in DL
30 ;-----
      CurPos      Proc      Near
                   Push      AX
                   Push      BX

35  service 2    Mov      AH,02      ;Interrupt 10
                   Mov      BH,00      ;Video page 0
                   Int      10h

40                   Pop      BX
                   Pop      AX
                   Ret
      CurPos      Endp

;-----
45 ;Data area
;      - Console messages
;      - ISO command strings

```

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```

;-----
;.Data

;Console messages

STitle          DB      0Ah
5 ;Char attribute (clr)
                  DB      'Boot Integrity Token System'
;String
                  DB      00h
;End of string marker
10 SSTitle       DB      0Ah
                  DB      'DOS-BITS Version 1'
                  DB      00h
                  DB      07h
                  DB      'Please insert card...'
15 SErase        DB      00h
                  DB      07h
                  DB      '
                  DB      00h
20 Erase         DB      07h
                  DB      '
                  DB      00h
                  DB      07h
                  DB      '
                  DB      00h
                  DB      07h
                  DB      'Password: '
                  DB      00h
25 BadPass       DB      07h
                  DB      'Incorrect. Please try again.'
                  DB      00h
                  DB      07h
                  DB      'Loading operating system...'
30 CdLck         DB      00h
                  DB      0Fh
                  DB      'Card is locked!'
                  DB      00h
                  DB      0Fh
                  DB      00h
35 CdLck2        DB      0Fh
                  DB      'Please see Security Manager.'
                  DB      00h
                  DB      07h
                  DB      'Keyboard Status: '
                  DB      00h
40 FileChk       DB      07h
                  DB      'Checking files: '
                  DB      00h
                  DB      07h
                  DB      'IO.SYS'
45 File2         DB      00h
                  DB      07h
                  DB      'MSDOS.SYS'
                  DB      00h
File3           DB      07h

```

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```

                                DB      'COMMAND.COM'
                                DB      00h
File4                          DB      07h
                                DB      'CONFIG.SYS'
5                               DB      00h
BadFile                        DB      07h
                                DB      'Missing or corrupted system
file!'
                                DB      00h
10 OKFile                      DB      07h
                                DB      'Files OK.  Booting...'
                                DB      00h

;Shared secret (card/PC) data
SharSec                        DB      00h

15 ;Reader and card command strings
InitRdr                        DB      04h,03h,0Fh,0D0h,0Ah
StCrdTp                        DB      03h,02h,02h,00h
RstCard                        DB      04h,03h,0Fh,0D0h,0Ah
PowerOn                        DB      04h,6Eh,01h,00h,00h
20 PowerOff                    DB      01h,4Dh
SelPbrFl                       DB      06h,0DBh,00h,0A2h,02h,7Eh,08h

;Operating system filenames
SysFile1                       DB      'IO      SYS'
SysFile2                       DB      'MSDOS   SYS'
25 SysFile3                     DB      'COMMAND COM'

;End, data area
Cseg                            Ends
END

```

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What is claimed is:

1. A method for reducing the possibility of corruption of critical information required in the operation of a computer comprising:
 - 5 storing the critical information in a device, communicating authorization information between the device and the computer, and causing the device, in response to the authorization information, to enable the computer to read
 - 10 the critical information stored in the device.
2. The method of claim 1 wherein the steps of communicating authorization information and enabling the computer to read comprise
 - 15 a user entering a password, and the device verifying the password.
3. The method of claim 1 wherein the authorization information comprises biometric information about a user.
4. The method of claim 1 further comprising
 - 20 storing a password in the device, in the device, comparing the stored password with an externally supplied password, and basing a determination of whether to enable the computer to read the stored critical information on the
 - 25 results of the step of comparing the passwords.
5. The method of claim 1 wherein the device comprises a microprocessor and a memory.
6. The method of claim 5 wherein the device comprises a pocket-sized card containing the
 - 30 microprocessor and the memory.
7. The method of claim 1 wherein said critical information comprises boot-sector information used in starting the computer.

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8. The method of claim 1 wherein said critical information comprises executable code.

9. The method of claim 1 wherein said critical information comprises system data or user data.

5 10. The method of claim 1 further comprising the computer booting itself from the critical information read from the device.

11. The method of claim 1 wherein the computer booting itself comprises executing modified boot code in
10 place of normal boot code.

12. The method of claim 11 further comprising storing the modified boot code in the form of a BIOS extension.

13. The method of claim 1 wherein the steps of
15 communicating authorization information and enabling the computer to read, comprise

the device passing to the computer, secret information shared with the computer, and

the computer validating the shared secret
20 information passed from the device.

14. The method of claim 1 wherein the authorization information comprises file signatures for executable code.

15. The method of claim 1 wherein the
25 authorization information comprises a user's cryptographic key.

16. The method of claim 13 wherein the shared secret information comprises a host access code.

17. The method of claim 1 wherein the stored
30 critical information includes file integrity information.

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18. A method of booting a computer, comprising
storing, in a device which is separate from the
computer, boot information, user authorization
information, and device authorization information in the
5 form of a secret shared with the computer,
providing a communication link between the device
and the computer,
receiving possibly valid authorization information
from a user,
10 in the device, checking the possibly valid
authorization information against the stored user
authorization information to determine validity,
if the password is determined to be valid, passing
the boot information and the shared secret information
15 from the device to the computer,
in the computer, checking the validity of the
shared secret information, and
if the shared secret information is valid, using
the boot information in booting the computer.
- 20 19. A method for initializing a device for use in
reducing the possibility of corruption of critical
information required in the operation of a computer
comprising:
storing the critical information in memory on the
25 device,
storing authorization information in memory on the
device, and
configuring a microprocessor in the device to
release the critical information to the computer only
30 after completing an authorization routine based on the
authorization information.
20. The method of claim 19 wherein said critical
information comprises boot information.

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21. The method of claim 20 further comprising storing file integrity information in the memory of the device.

22. The method of claim 20 further comprising
5 storing system or user data in the device.

23. The method of claim 20 further comprising storing executables in the memory of the device.

24. A portable intelligent token for use in effecting a secure startup of a host computer comprising
10 a housing,

a memory within said housing, the memory containing information needed for startup of the host computer, and

a channel for allowing the memory to be accessed
15 externally of the housing.

25. The token of claim 24 wherein said memory also contains a password for authorization, said token further comprising

a processor for comparing the stored password with
20 externally supplied passwords.

26. The token of claim 24 wherein the memory stores information with respect to multiple host computers.

27. The token of claim 24 wherein said housing
25 comprises a pocket-sized card.

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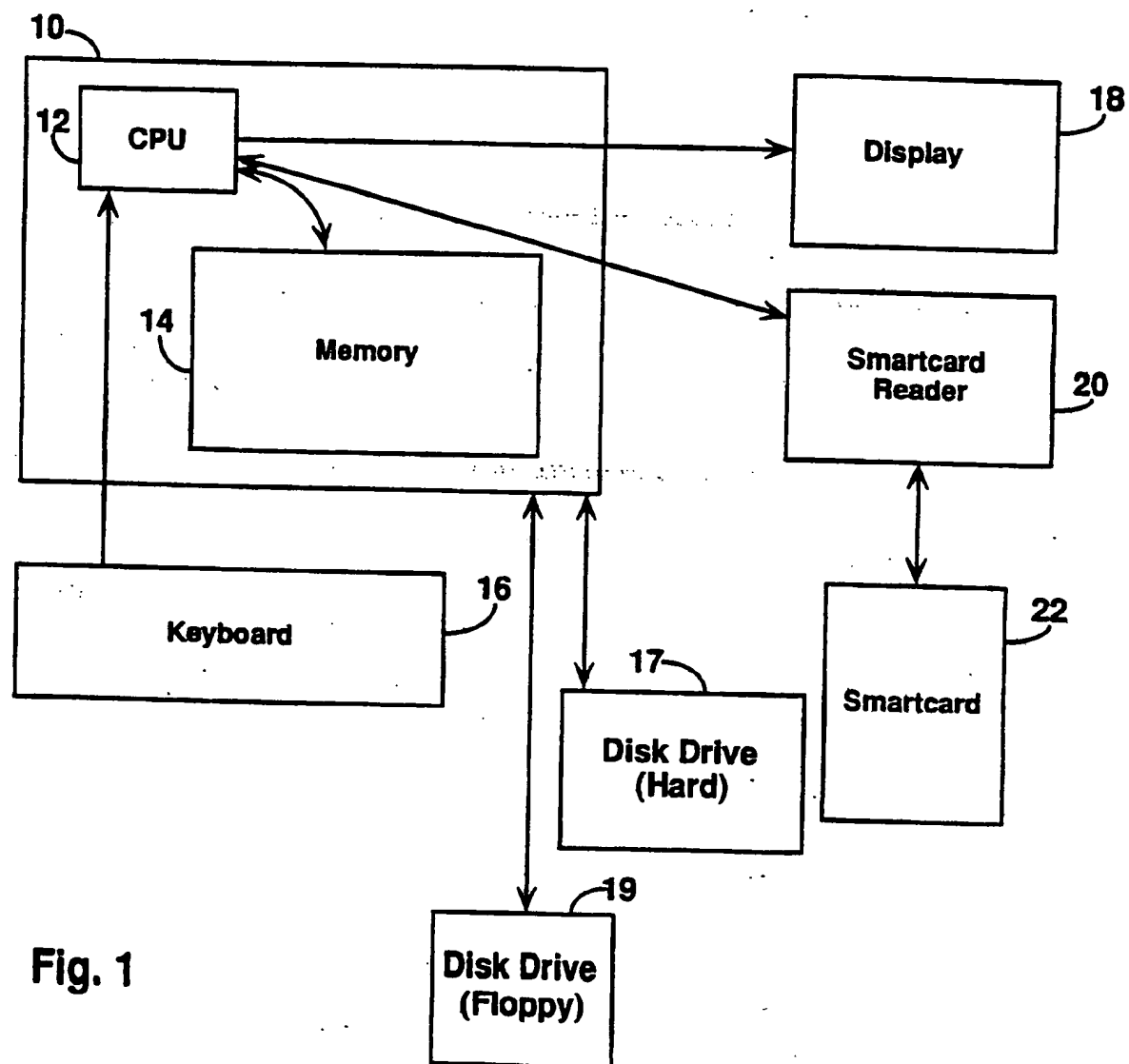


Fig. 1

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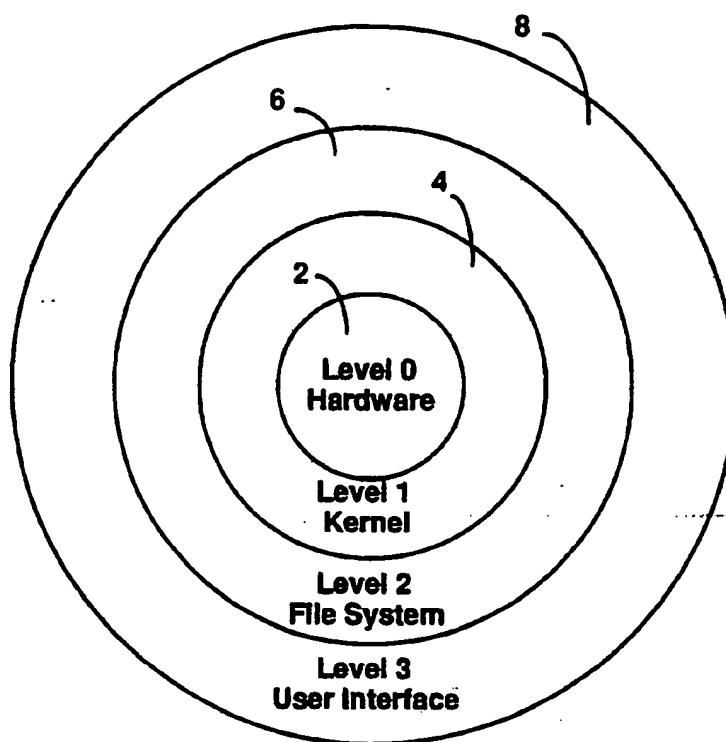


Fig. 2

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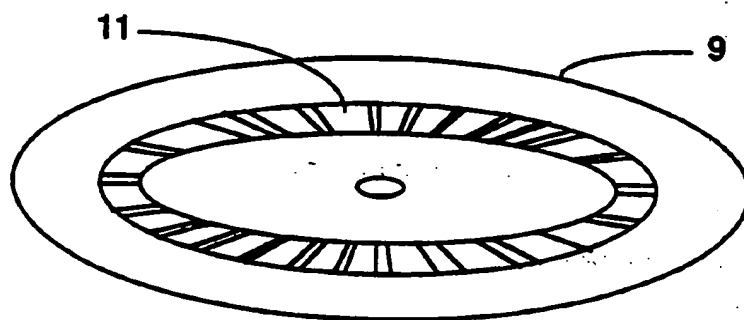
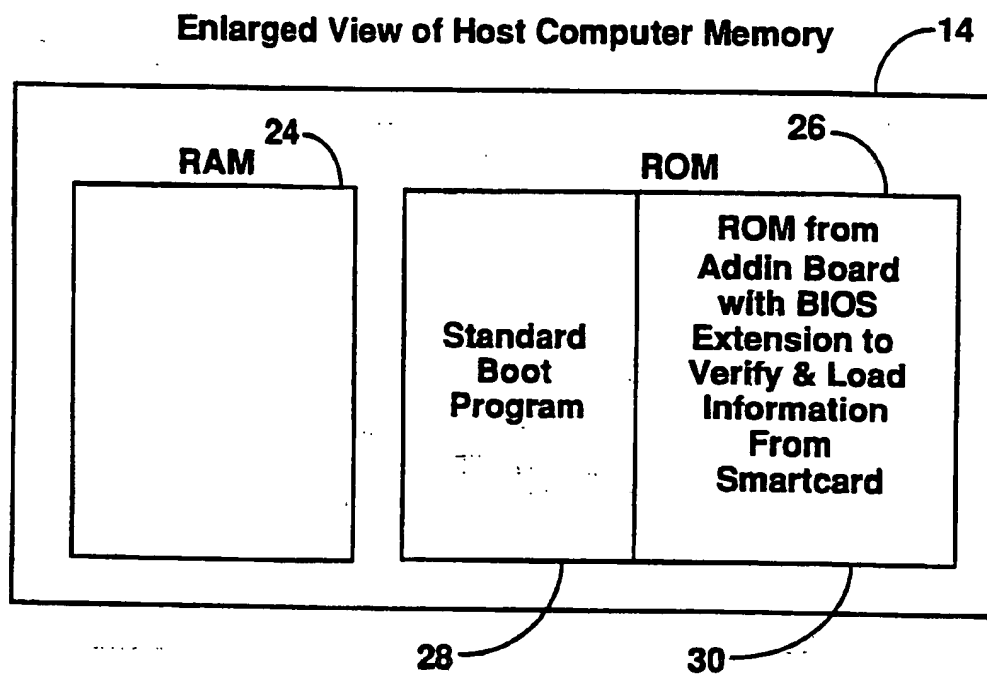
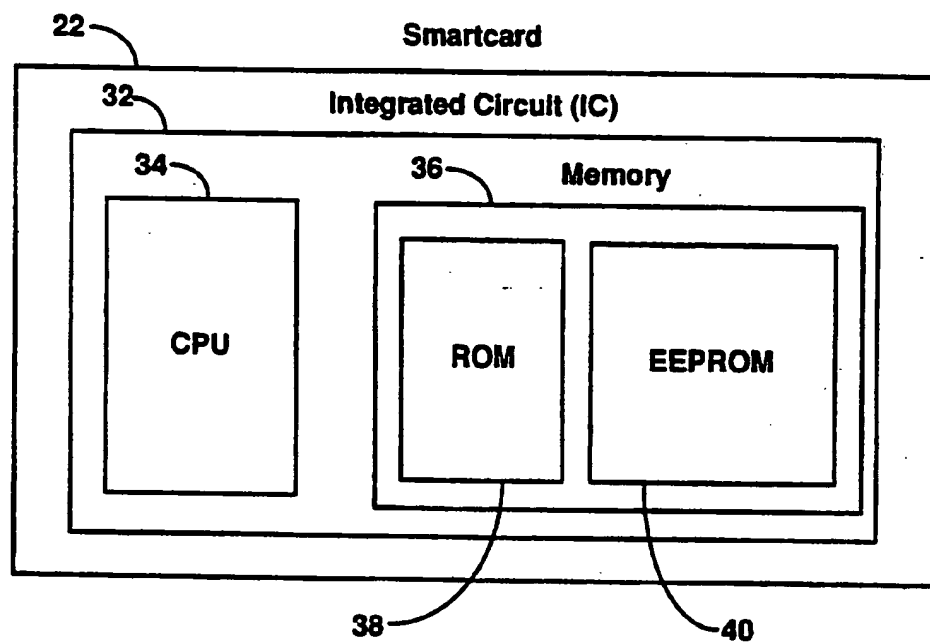


Fig. 3

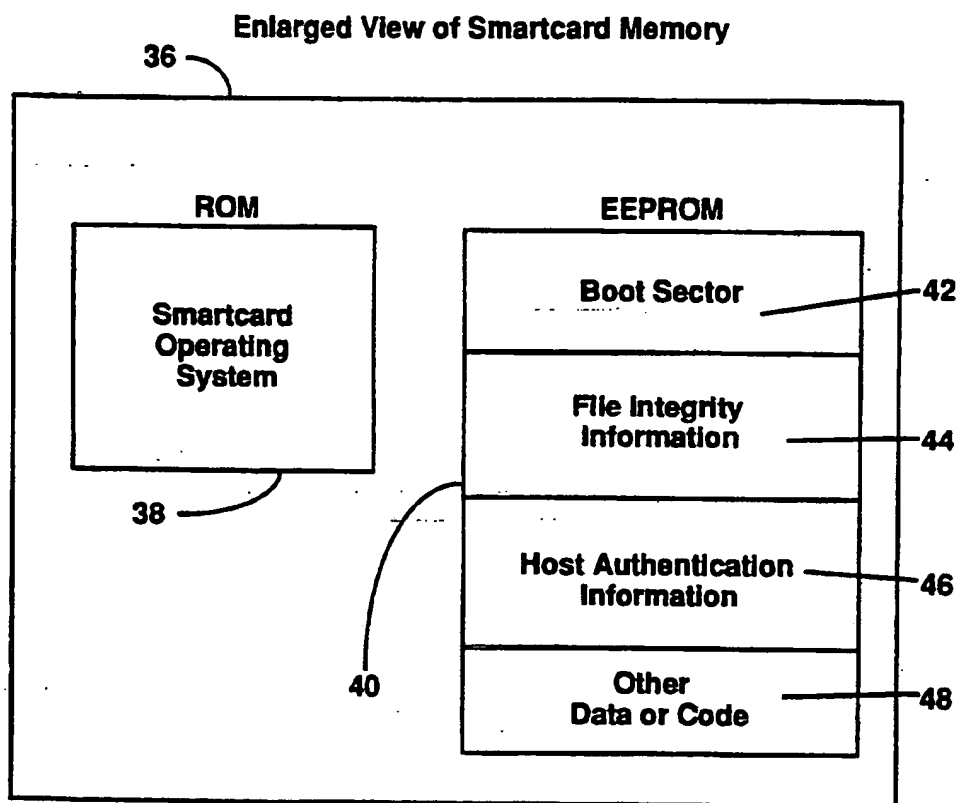
4/10

**Fig. 4**

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**Fig. 5**

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**Fig. 6**

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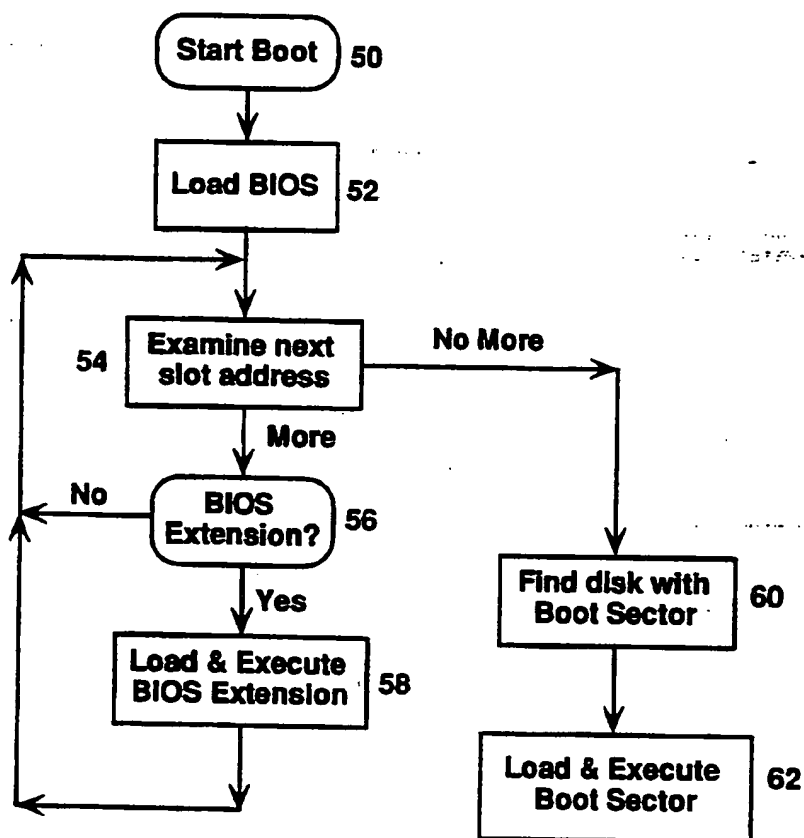


Fig. 7

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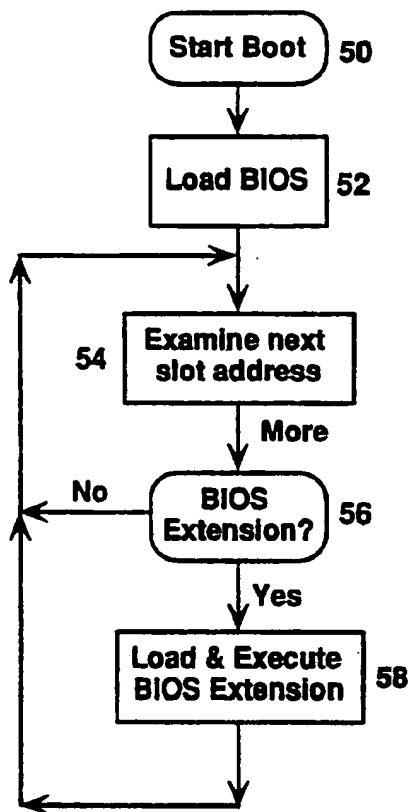


Fig. 8

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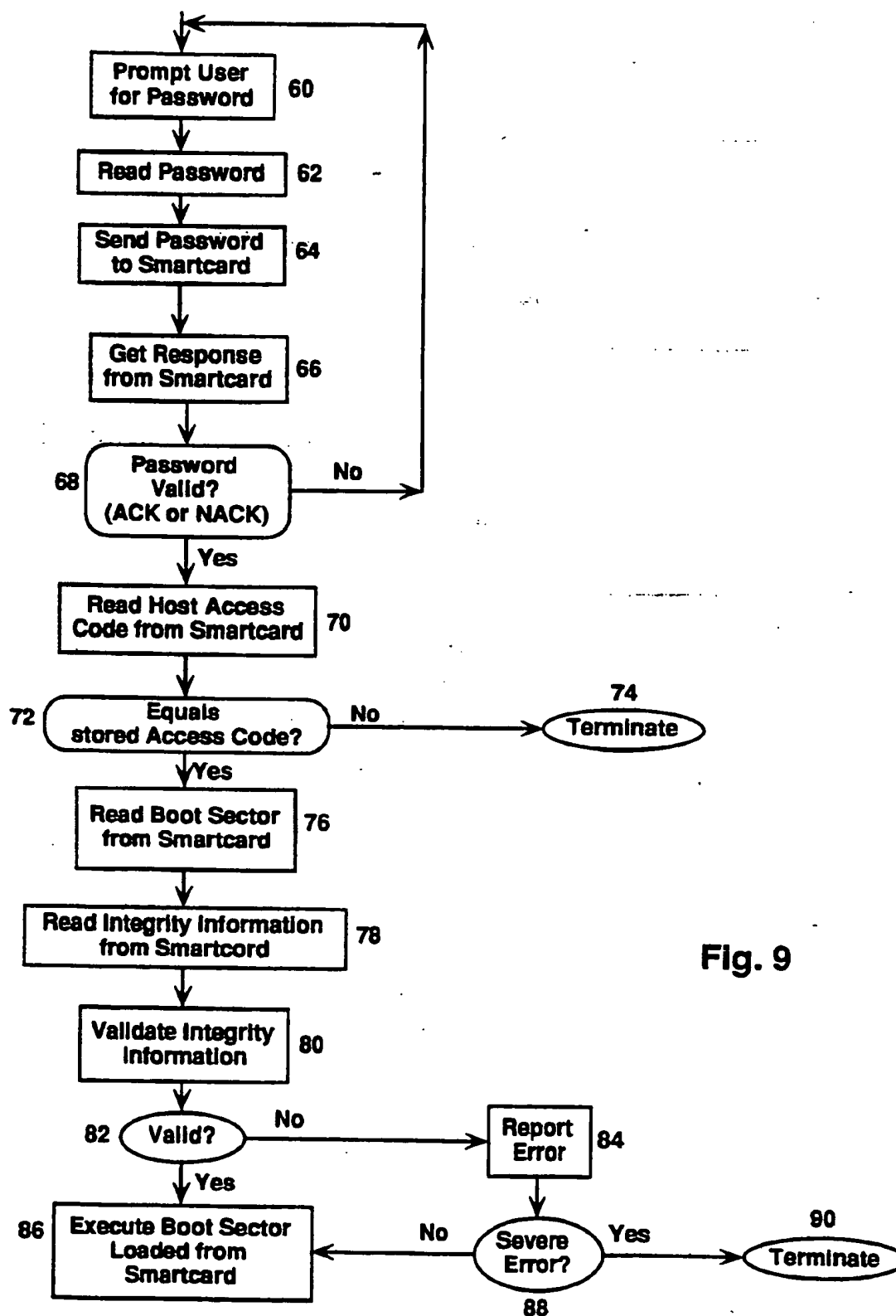


Fig. 9

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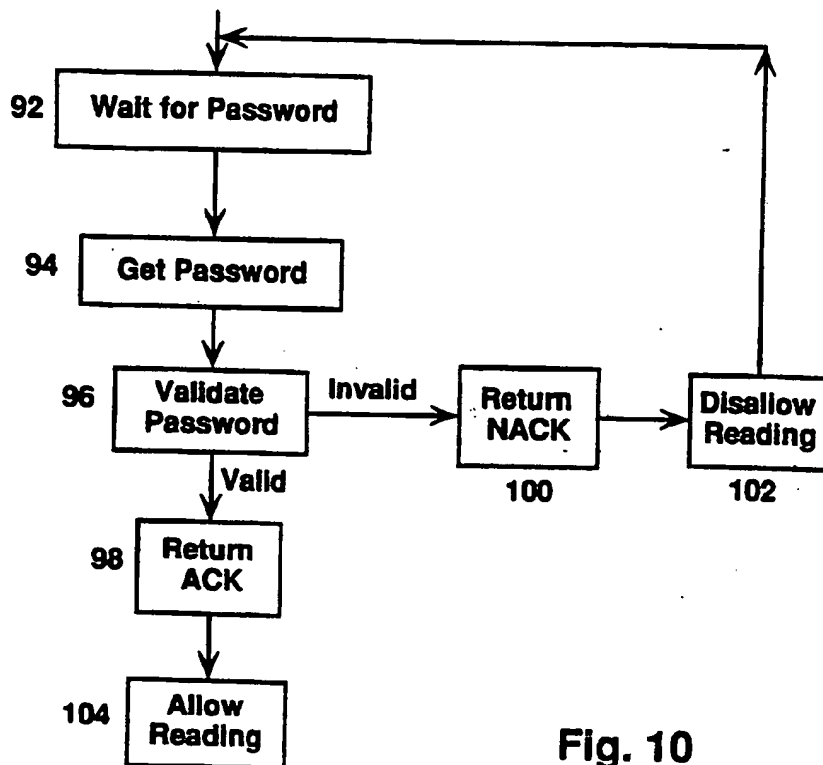


Fig. 10

INTERNATIONAL SEARCH REPORT

PCT/US93/01675

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) : G06F 12/14, 7/04, 3/06

US CL : 380/25, 23, 3, 4, ; 235/382.5, 382, 380/395/600, 800

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/700, 725

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US,A, 4,829,169 (WATANABE) 09 MAY 1989 See figures 3,4; col. 5, lines 28-33 and 50-59; col. 8, lines 55-col. 12, line 16.	1-27
X,P Y,P	US,A, 5,146,499 (GEFFROTIN) 08 SEPTEMBER 1992 See col. 1, lines 28-56; col. 2, line 51-col. 3, line 13; col. 7, lines 1-21, col. 10, lines 60-66	1-6, 8, 9, 13-17, 19, 24-27 7, 10-12, 18, 20-23
Y,P	US,A, 5,120,939 (CLAUS ET AL) 09 JUNE 1992 Figure 1,5; col. 8, line 58-col. 10, line 50.	1-27

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

* Special categories of cited documents:	T	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"O" document referring to an oral disclosure, use, exhibition or other means		
"P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 03 MAY 1993	Date of mailing of the international search report 27 MAY 1993
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. NOT APPLICABLE	Authorized officer PAUL HARRITY INTERNATIONAL DIVISION Telephone No. (703) 305-9677

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US93/01675

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 5,036,461 (ELLIOTT ET AL) 30 JULY 1991 See figs 4 and 5	1-27
A	US,A, 4,935,962 (AUSTIN) 19 JUNE 1990 Figures 2 and 3	1-27